The future of Swedish forests

An analysis of two contrasting policy scenarios

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Supervisors: Ragnar Jonsson and Ola Sallnäs

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Master Thesis no. 205
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Abstract

Constant increases in oil prices, greenhouse gas emissions, and concerns about energy import dependence are shifting focus towards renewable resources. In 2009 the European parliament and the council of the European Union have published the directive in which is stated that the mandatory national targets should consist of 20% share of energy from renewable sources and 10% energy from renewable sources in transport in all Member States by the year 2020 (Directive 2009/28/EC).

Bioenergy, production of timber and pulp, possibility to use forests for recreation, water quality, availability of mushrooms, berries and game (non-tree forest products) quality and capacity to contribute to a positive carbon balance are all essential parts of forestry in Sweden (Gustafsson 2009). In the light of changes that are currently affecting forest sector in Europe, Sweden has to face various challenges in order to maintain sustainability of its forest sector.

The main objectives of this study are to produce and analyse two contrasting scenarios as regards overarching policy directions: a *biodiversity scenario*, exploring the impacts on Swedish forest resources when biodiversity is prioritized in forest management, and *wood energy scenario*, simulating forest development when the main objective of forest management is to maximize woody biomass production. The results indicate that, depending on the objective, different trade-offs would be necessary.

Keywords: Policy scenarios, forest resources, future, wood energy, biodiversity, EFSOS.

Preface

The North European Regional Office of the European Forest Institute-EFINORD promotes research cooperation within the Nordic-Baltic Sea-North Atlantic region. EFINORD Regional Office, located in Copenhagen, Denmark, was launched in late 2010. Within the framework of sustainable forestry, the two thematic issues of EFINORD Regional Office are (i) biomass production and intensive forest management and (ii) ecosystem services. This thesis was conducted as a complement to the *Facts and Figures of the EFINORD Forest Sector,* a baseline study for the EFINORD work plan within the theme of biomass production and intensive forest management coordinated by Professor Tomas Lundmark, Swedish University of Agricultural Sciences (SLU), and Mika Mustonen, Head of office at EFINORD.

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1. Background and objectives

Despite accounting for only 0.14 % of the world population and 0.32 % of the world land area, Sweden plays a prominent role in the production and export of forest products (FAO 2009). Thus, Sweden is the world’s second largest exporter overall of paper, pulp and sawn timber (Swedish Forest Industries Federation 2009). The Swedish forest industry is highly export-oriented, e.g., paper exports amounted to 89% of the production in 2009 (Swedish Forest Industries Federation 2010). Thus, it is reasonable to conclude that international, notably European, developments in the use of wood resources are likely to have far-reaching implications for the Swedish forest-products industry as well as for the forest sector as a whole (Jonsson et al. 2011).

In 2009 the European parliament and the council of the European Union (EU) published the directive in which mandatory national targets regarding the use of renewable energy sources are set out. For the EU as a whole, renewable energy sources should account for at least 20 % of total energy consumption, whereas a minimum of 10% of the energy used in petrol and diesel transport should be from renewable sources by the year 2020. Furthermore, the same directive states that in order to use the full biomass potential, greater mobilisation of existing timber reserves and development of new forestry systems needs to be promoted (Directive 2009/28/EC).

Wood energy, according to FAO (2008), if it is produced with efficient technology, is highly competitive with fossil fuel energy and can offer some of the highest levels of energy and carbon efficiency among bioenergy feedstock. Sweden is one of few countries in the EU with both significant supply and consumption of wood for energy.

Hence, energy supply and demand can be expected to become a major driver of changes in the Sweden’s forestry sector due to two main reasons: (i) the global concern over climate change and global warming and (ii) the possibility to increase energy security. Thus, increased demand for woody-biomass can be expected. Due to the increased demand and the resulting increased competition for raw material, Sweden will face challenges in the forest sector, especially in its pulp and paper industry (Egnell 2009).

Further, in addition to producing timber, pulp, and biomass for energy, forests are expected to provide other ecosystem services such as mushrooms, berries, game (non-wood forest products), recreation, water quality support and regulation, and contribute to a positive carbon balance (Gustafsson 2009; Bestard et al.. 2010).

All in all, it is reasonable to conclude that the Swedish forest sector will face increasing, and at times conflicting, demands in the future. The objectives of this thesis are to produce and analyse two contrasting scenarios as regards overarching policy choices or directions. The study aims at providing results that can be used for a assessing the development of the Swedish forest resource given different policy directions. Trade-offs between the different policy objectives as well as possible win-win situations will be highlighted. Further, the scenario outcomes are compared with other European scenario analyses, mainly the modelling results as regards the development of the Swedish forest resource in the European Forest Sector Outlook Study II (EFSOS II). Since the results of different modelling approaches are not directly comparable, the comparisons are made on a general level, such as the direction of development of different key indicators.

The two scenarios modelled are:

- A *Biodiversity scenario,* exploring the impacts on Swedish forest resources when biodiversity is prioritized in forest management.
- A *Wood energy scenario:* simulating forest development when the main target of forest management is to maximize woody biomass production, given initial state of the forest resource

More details on how the scenarios were set up are presented in section 2.3.

2. Materials and methods

2.1 The Heureka Forestry Decision Support System

Scenarios were generated using the Heureka simulation software. The Heureka Forestry Decision Support System (DSS) is a suite of freely available software, developed and hosted by the Swedish University of Agricultural Sciences (SLU). The system covers the whole decision support process from data inventory to tools for selecting among plan alternatives with multi-criteria decision making techniques [1].

The application used for this research was Plan Wise and the type of planning used was strategic planning. Plan Wise application has two main components:

Treatment Program Generator (TPG) is a growth and yield simulator that calculates an alternative treatment program for each stand

Heureka Optimization Generator System (HOPS) is used to compile and solve mixed integer programming and linear programming problems for choosing between optional treatment programs

2.2 Initial state

The data used in this study comes from the Swedish National Forest Inventory 2009. An overview is given in Table 1.

Of the total land area approximately two thirds of Sweden is forested land area (Swedish Forest Agency 2009). Total forest area in Sweden comprises twenty-eight million hectares (ha); of which 23.7 million ha is productive forest land. Swedish forests are dominated by conifers; Norway spruce (*Picea abies*) accounts for forty-two percent, pine (*Pinus sylvestris*) for thirty-nine percent, broadleaves for sixteen percent (of which birch (*Betula pendula*) eleven percent-

Table 1. Initial state (Swedish Forest Agency 2009)

Initial state				
Number of treatment units	Total area (million ha)	Productive area (million ha)	Mean volume (m^3/ha)	Mean age (years)
6029	23,7	23,7	128,97	61,62

2.3 Scenario descriptions

2.3.1 Biodiversity scenario

This scenario was created in overall accordance with the *biodiversity scenario* presented in EFSOS II (UN 2011). The main properties are:

- Increasing the forest area set aside for biodiversity conservation with an additional 5%, by reducing forest available for wood supply by 5 % .

- Increase rotation periods, i.e., increase minimum allowable final felling age by 30 %
- After clear felling, 50 % of areas which are currently dominated by coniferous species are converted to broadleaved dominated areas, and supporting tree species compositions closer to natural diversity
- No logging residues extraction of any kind is applied
- The time frame for the simulation was 20 periods, i.e., 100 years)

In the biodiversity scenario the model was set to smooth harvest levels throughout the simulation; pushing the levels of harvests to be as equal as possible in each period, creating an even flow harvests.

2.3.2 Wood energy scenario

As already mentioned, both the expectations and actual use of woody biomass for energy are on the rise. This is the backdrop for the so-called *wood energy scenario*. As well as the *biodiversity scenario* the *wood energy scenario* was created to resemble the corresponding scenario, the *Promoting wood energy scenario*, in EFSOS II (UN 2011).

Main settings of the scenario are following:

- Minimum allowable final felling age was decreased by forty percent
- Harvest residues extraction was allowed (see Table 2 for details)
- Lodgepole pine (*Pinus contorta spp.) was allowed to remain*
- Table 2 presents the removal rates for different assortments of woody biomass used
- The time frame for the simulation was 20 periods (100 years)

In the wood energy scenario, an additional constraint was added to the optimization model. The constraint limited the amount of possible harvests, to prevent a continuous decrease of the growing stock. A decrease of the growing stock was allowed only for the first three periods.

Table 2. Residues removal in Promoting wood energy in EFSOS II (UN 2011)

Definition	%
Share of felled stemwood that is really removed (as logs) in clear-fellings	0,97
Share of topwood (harvest residues) that is removed in clear-fellings	0,593
Share of branches (harvest residues) that is removed in clear-fellings	0,593
Share of foliage (harvest residues) that is removed in clear-fellings	0
Share of coarse roots that is removed in clear-fellings	0,58
Share of deadwood present at a site that is removed in clear-fellings	0

2.4 *Recreation index*

As the recreation value of forests is of high importance for people in Sweden – according to Lindhagen as cited in Hörnsten (2000) Swedes visit forest 1-2 times every 2 weeks – it is of interest in this thesis to observe the effect that different scenarios might have on this ecosystem service. The recreation index presented in the results is a product of the Heureka simulations and it is roughly defined as:

For bare land and plantations (<2 m height)

It *increases* with increased tree size diversity

It *decreases* with increased amount of deadwood

It *decreases* with increased amount of downed logs

It *decreases* with increase in residues harvesting

2. For young stands > 2 m, and before first thinning
   - As above, plus:
   - it *decreases* with increased occurrence of conifer plants, broadleaves are preferred
3. For older stands
   - As above, plus:
   - No. of stems (many large trees are preferred before small trees)
   - Soil damage (occurrence of soil damages from harvest machines etc. has a negative impact on index)[3]

3. Results

3.1 Biodiversity scenario

In the initial state, the total standing volume in forest area studied is 3 100 million m^3. The *biodiversity scenario* records a significant increase in growing stock, stabilizing at around four billion m^3. This build-up in growing stock is taking place the first fifty years (Figure 1).

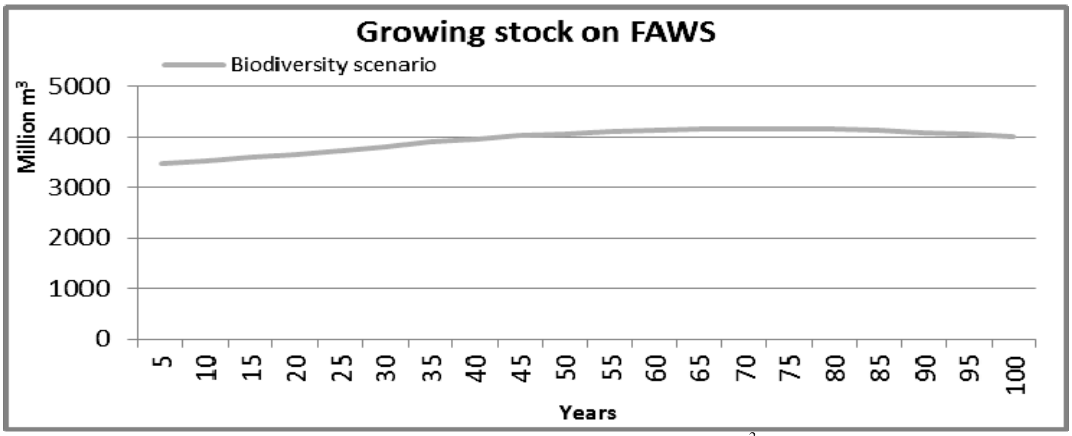

Figure 1 Total growing stock on in biodiversity scenario (in million m^3)

The detailed development of the age class distribution after 5, 50 and 100 years (periods 1, 10 and 20) is presented below (Figure 2). There is a significant increase in area in the highest age class. From the first period until the last one the area in the highest age class almost doubles.

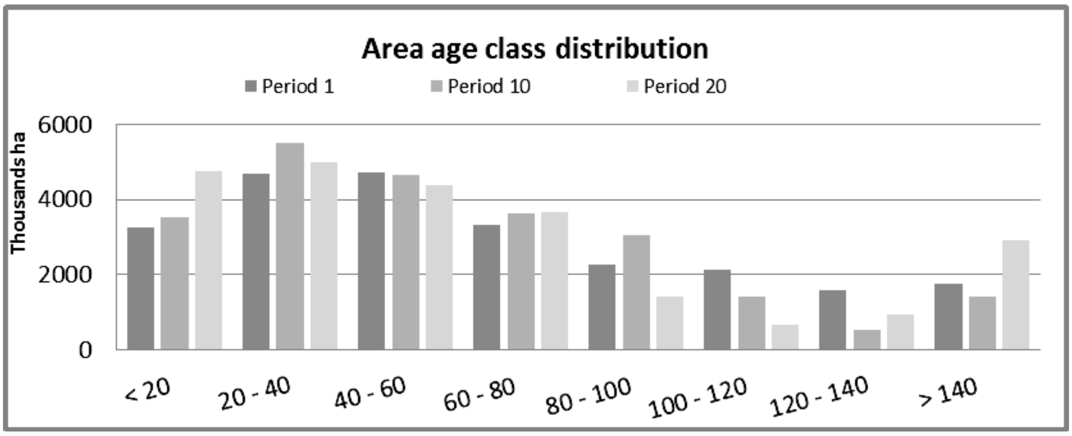

Figure 2 Area age class distribution throughout the simulation (1000 ha)

As a result of the optimization model used, harvesting is at the same level in all periods. Total harvesting presented includes all types of wood extraction (cleaning, thinning and final felling). Figure 3 below shows the development of annual harvest volume and net annual increment for the biodiversity scenario over the 100 year-period simulated.

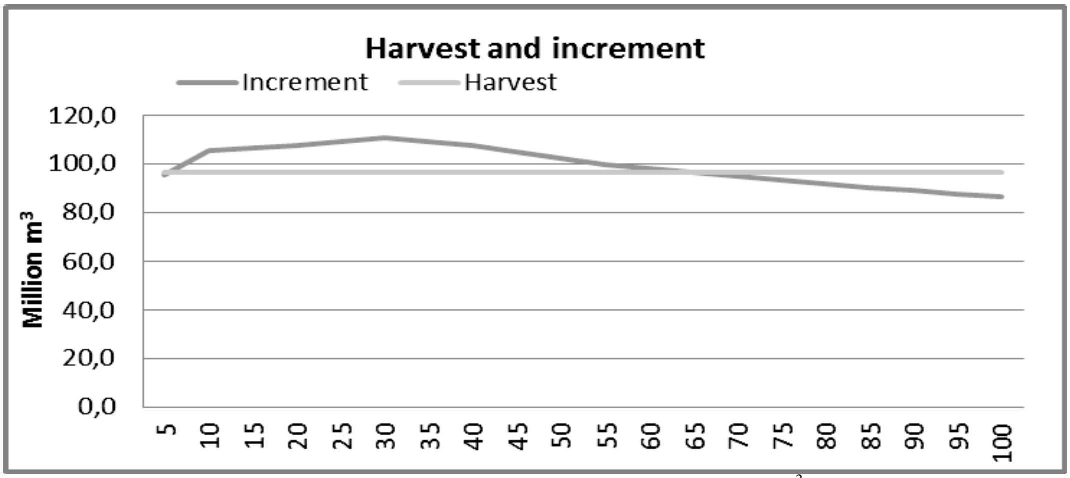

Figure 3 Annual harvested volume and net annual increment (in million m^3)

Being directly influenced by the development of the growing stock, both carbon stock and deadwood increase over time in the biodiversity scenario. Below, the development of total carbon stock and the amount of total deadwood over time is presented (Figures 4 and 5).

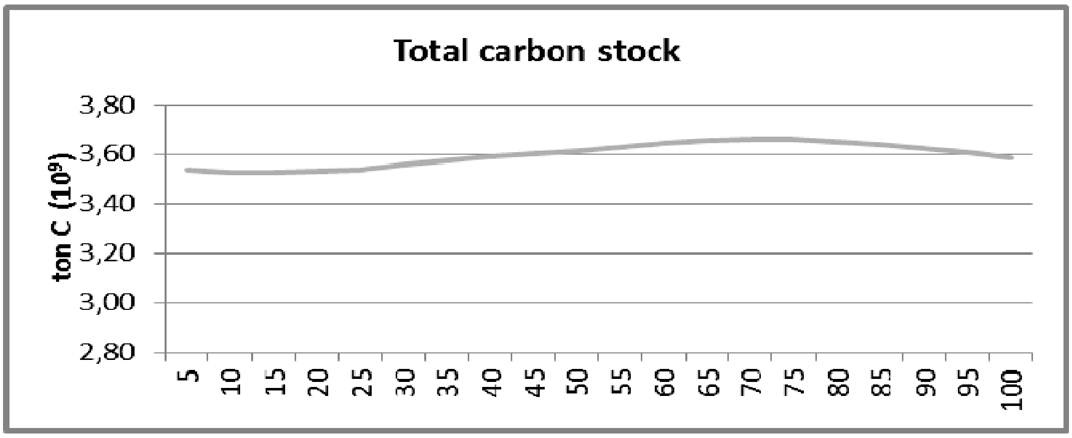

Figure 4 Total amount of carbon stored in hundred years' time (ton C)

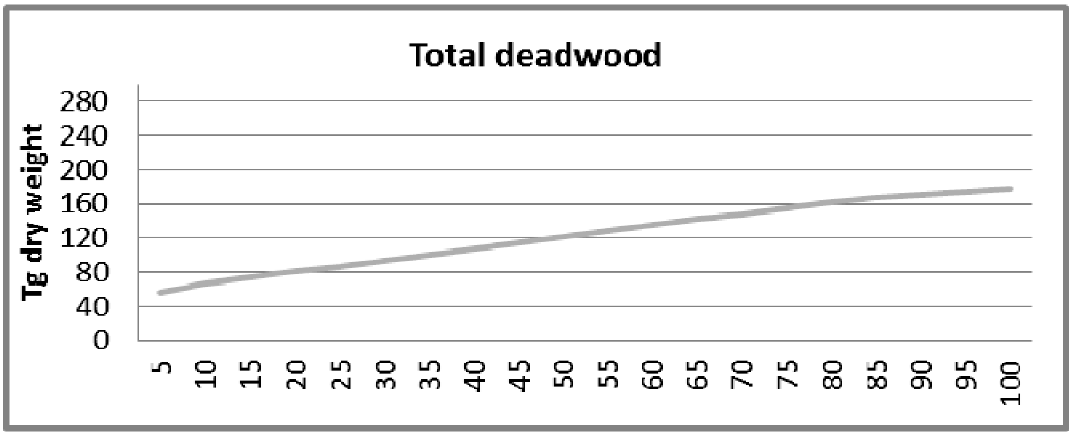

Figure 5 Total amount of deadwood in hundred year time (Tg dry weight)

Recreation index development, presented in a graph below, has a negative connotation of development, but it does not change significantly (Figure 6).

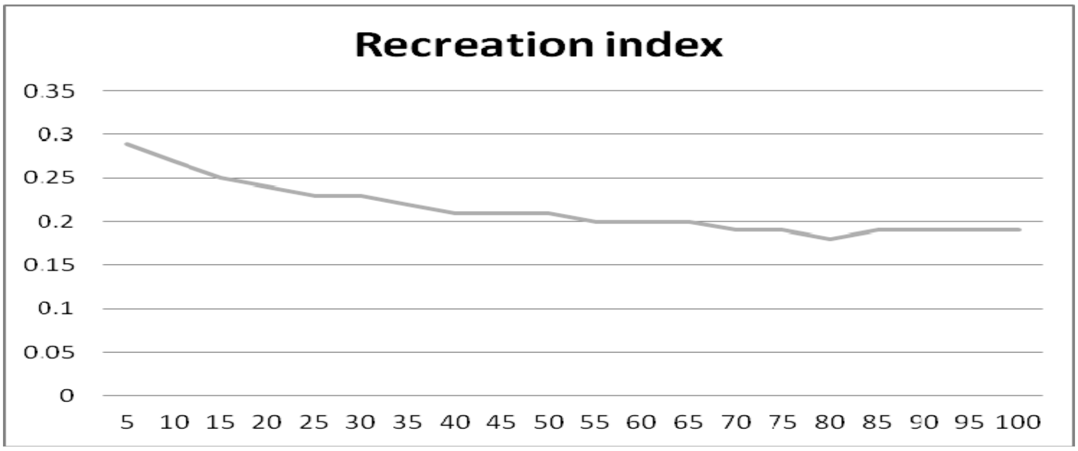

Figure 6 Recreation index development (relative scale 0-1)

3.2 *Wood energy scenario*

In the *wood energy scenario,* the growing stock is reduced to around 2 800 million m^3 (Figure 7). This decrease, which occurs the first ten years, is a result of minimum allowable final felling age being lowered by forty percent.

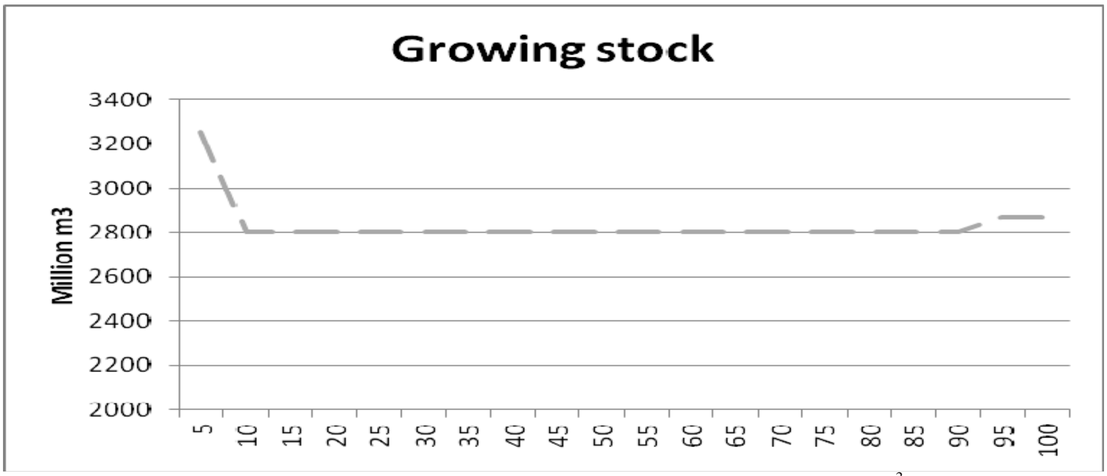

Figure 7 Total growing stock on studied area in wood energy scenario (in million m^3).

As can be expected, the age class distribution changes significantly over time. Hence, there is no area representation in the higher age classes after fifty years (Figure 8).

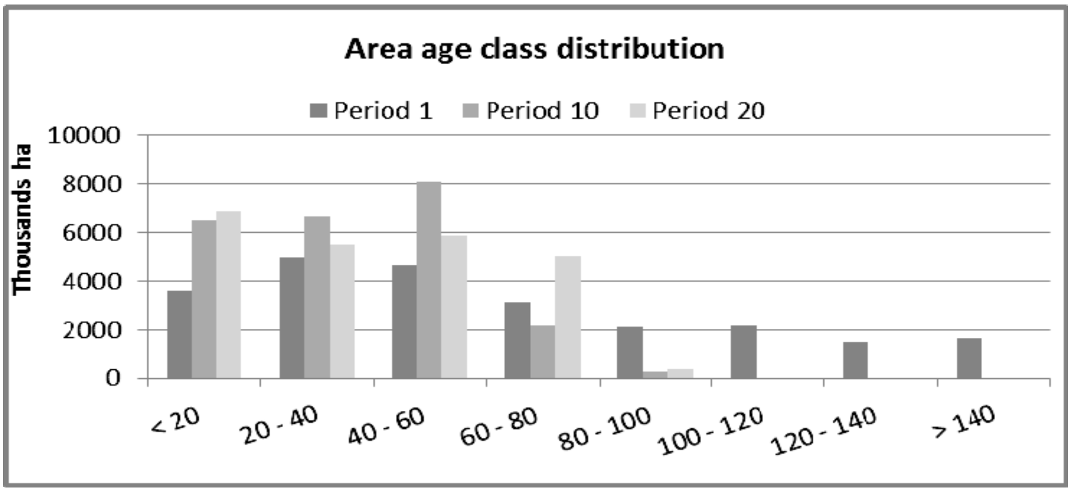

Figure 8 Area age class distribution throughout the simulation (1000 ha)

Large harvesting volumes the first ten years of the simulation is later on replaced by stable increment and harvest rates as a result of the constraint discussed earlier. The very high harvest volume from the first period is pushed back to more "normal" levels, varying from 80 to 130 million m^3. On average, the annual potential harvest level is 114 million m^3 on average, which is about twenty-two percent higher than current harvest levels. More detailed information on the development of harvests and increment over time is found below (Figure 9).

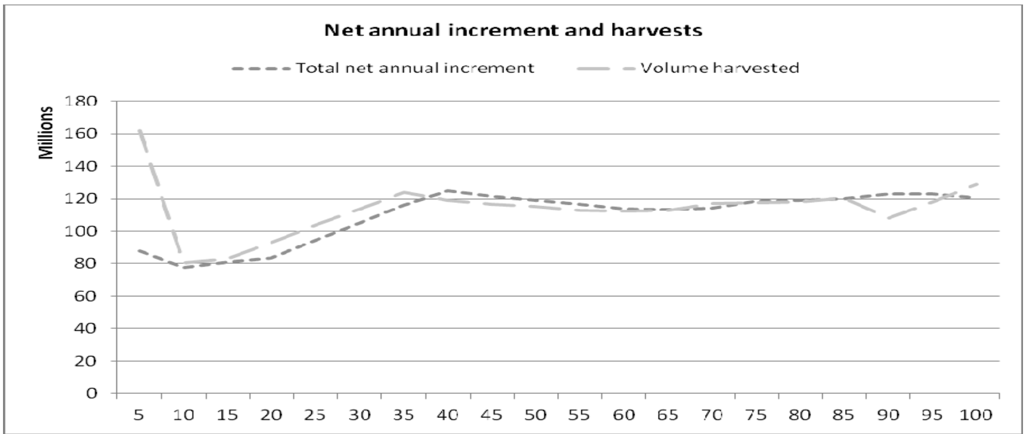

Figure 9 Annual harvested volume and net annual increment (in million m^3)

Unlike the biodiversity scenario, the wood energy scenario includes harvest residues extraction. Since the residues extraction is connected with total harvests levels, because of the previously stated reason, results in the first period are significantly higher than in the other periods. Five million tons could be harvested annually, on average (Figure 10).

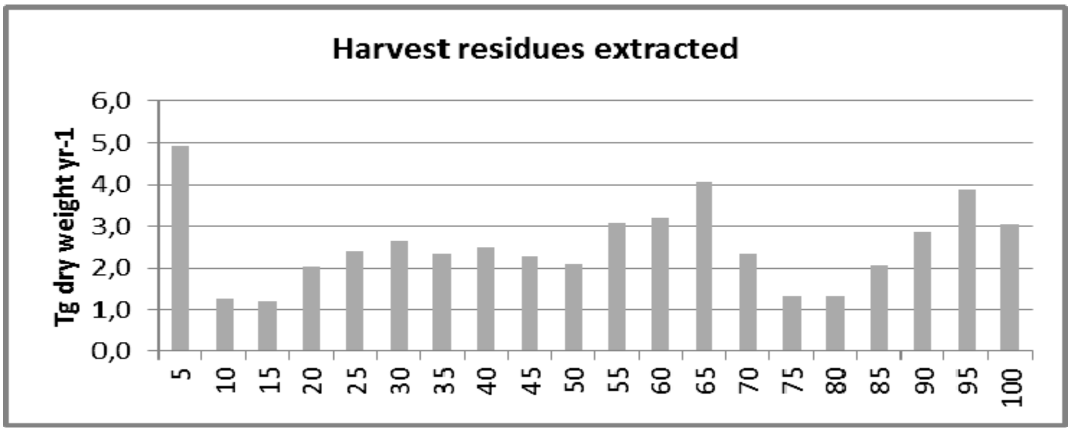

Figure 10 Amount of harvest residues extracted throughout the simulation.

Figure 11 shows total carbon storage. On average, the level is about eleven percent higher in the biodiversity scenario. A number of scientists agree that removing residues leads to a decrease in soil carbon (Johnson and Curtis 2001; Agren and Hyvonen 2003, as cited in Eriksson 2007). The results of this thesis show the same. Hence, the soil carbon stock, due to significant removals of harvest residues, is decreasing throughout the simulation period (Figure 12).

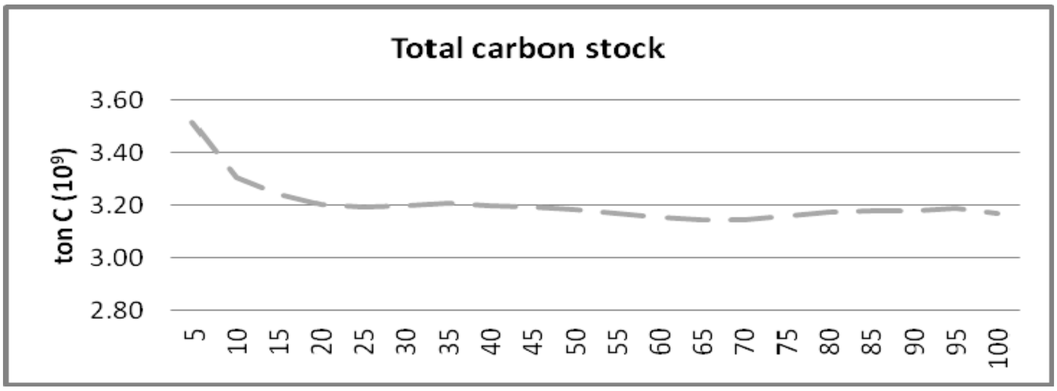

Figure 11 Total amount of carbon stored (in million tons)

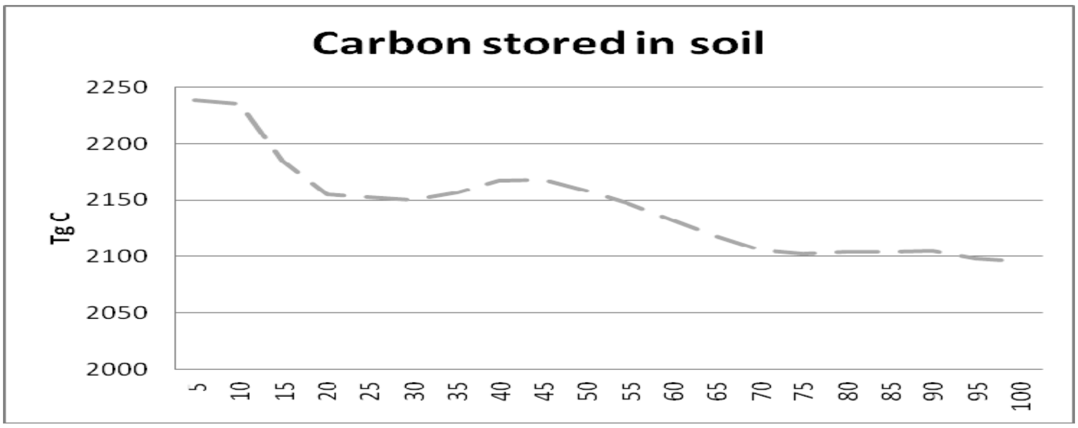

Figure 12 Carbon stored in soil in *wood energy scenario* (in millions tons C).

The amount of total deadwood is significantly lower than in the biodiversity scenario, due to harvest residues extractions in wood energy scenario and lower average rotation length. The development of total deadwood in the wood energy scenario can be observed below (Figure 13).

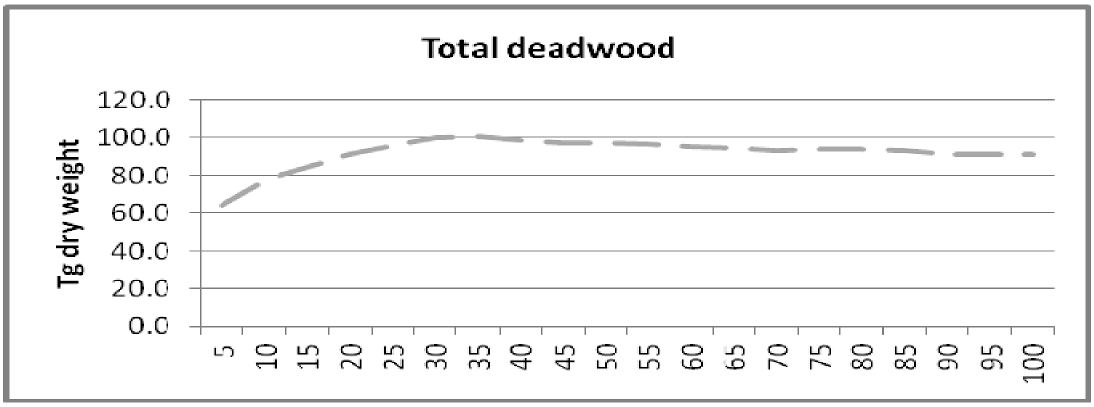

Figure 13 Total amount of deadwood accumulated in the study area (in Tg dry weight

The development of the recreation index results does not differ much between the two scenarios, in *wood energy scenario* the development is also on a continuous decrease (Figure 14).

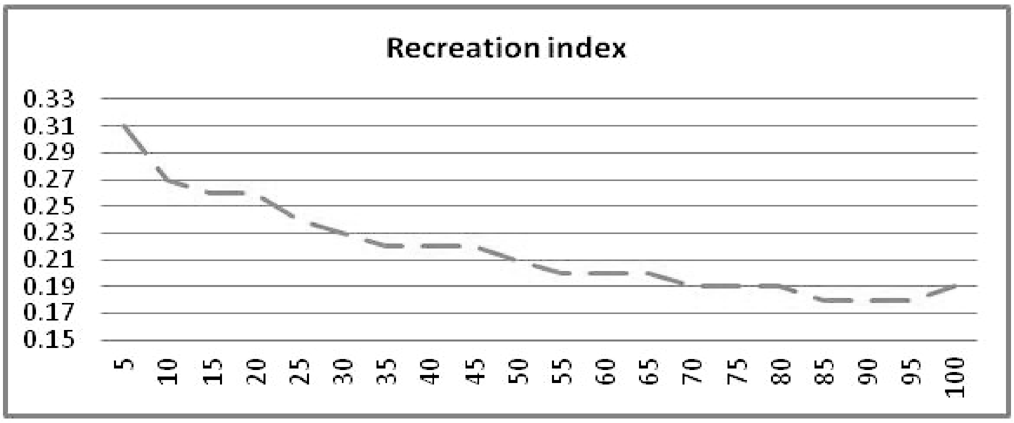

Figure 14 Recreation index *wood energy scenario* (relative scale 0-1).

Table below presents an overview of key forest indicators throughout the simulation (Table 3).

Table 3. Key forest resource development, presented in three periods.

FOREST RESOURCE		Scenario					
	Unit	Biodiversity			Wood energy		
year		5	50	100	5	50	100
period	5 years	1	10	20	1	10	20
Forest available for wood supply	1000 ha	23720	23720	23720	23720	23720	23720
Growing stock	million m3	3483	4066	4000	3255	2804	2868
	m3/ha	146.84	171.43	168.62	145.96	121.03	109.47
Fellings	million m3/yr	96	96	96	162.1	115	129
	m3/ha/yr	4.0	4.0	4.0	6.8	4.8	5.4
Increment	million m3/yr	95	102	86	88	117	120
	m3/ha/yr	4.0	4.3	3.6	3.7	4.9	5.1
Extracted residues	Tg dry weight/yr	-	-	-	4.9	3.1	3.0
Carbon in soil	ton C (10'9)	2189.8	2125.4	2049	2186.46	2168.6	2098.9
Lying deadwood	million m3	143	414	614	223	437.40	406.20
Standing deadwood	million m3	67.92	98.45	131.09	52.00	57.23	58.67
Total deadwood	million m3	210.53	512.46	745.40	274.90	494.63	464.87
Recreation index	relative scale 0-1	0.29	0.21	0.19	0.29	0.21	0.23

3.4 Comparison of key forest indicators with EFSOS II

Both of the scenarios created in this thesis were designed to as much as possible resemble the corresponding EFSOS II scenarios. However, due to different DSS used, assumptions somewhat differ from those in the EFSOS II study. Nevertheless, the basic assumptions behind each of the scenarios are similar and therefore it is interesting to present the similarities and differences between the developments of the key forest resources.

3.4.1 Biodiversity scenarios

The figures below present area age class distribution and growing stock development for the two *biodiversity scenarios* (Figure 15 and Figure 16). It can be observed that both management scenarios will lead to increases in growing stock as well as the area in the older age classes and therefore, presumably increased biodiversity values. Notably, only in the Heureka scenario would there be any forest in the highest age class by year 2030.

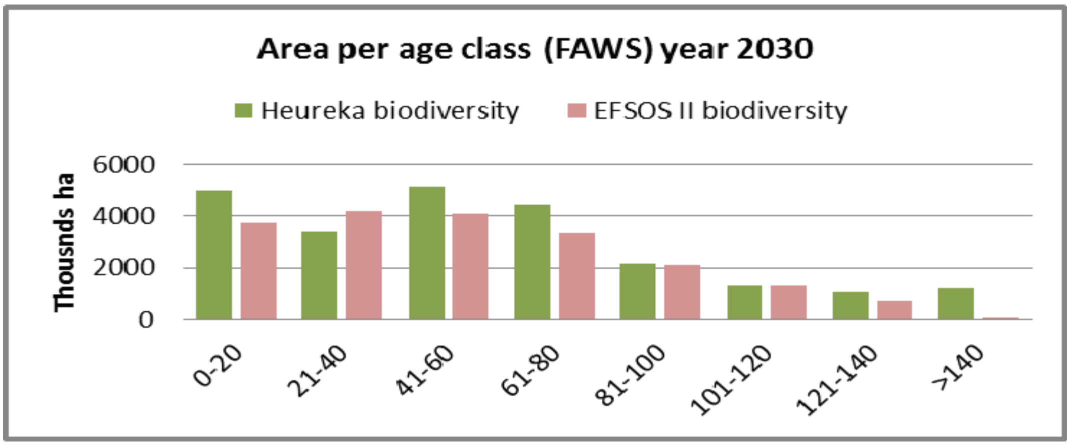

Figure 15 Age class distribution in year 2030

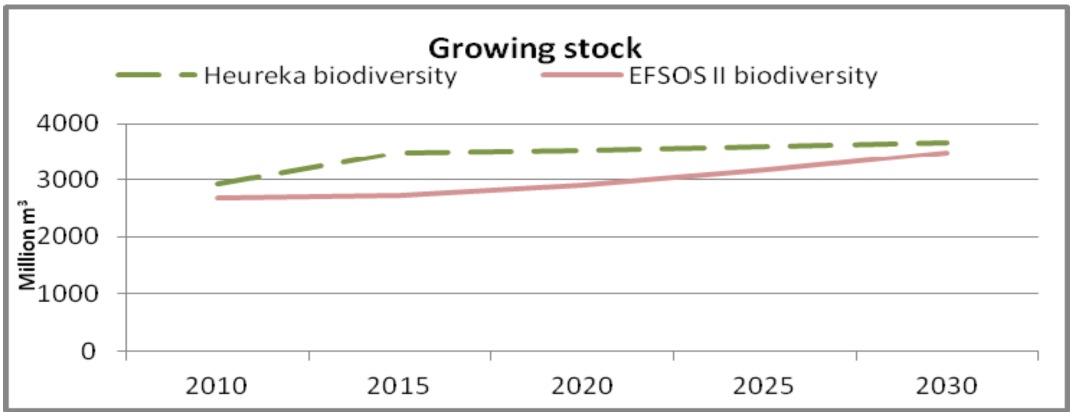

Figure 16 Total growing stock (in million m^3)

The harvest level is considerably higher in the Heureka *biodiversity scenario* (henceforth HBS) than in the corresponding EFSOS II scenario (Figure 17). Nevertheless, in the HBS the amount of deadwood is increasing, while this is not the case in the EFSOS II *biodiversity scenario* (Figure 18). This is most likely due to the increased thinnings regime applied in the EFSOS II *biodiversity scenario*.

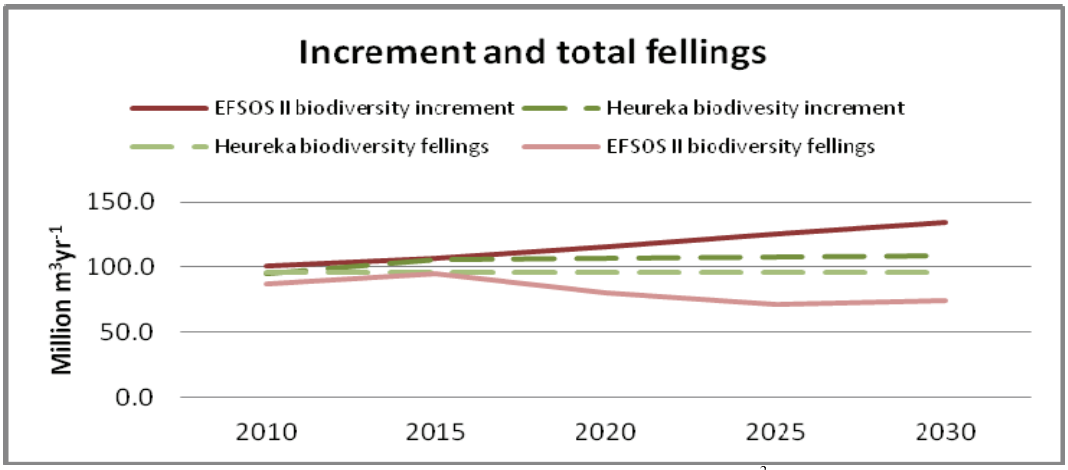

Figure 17 Net annual increment and gross annual fellings (in million m^3)

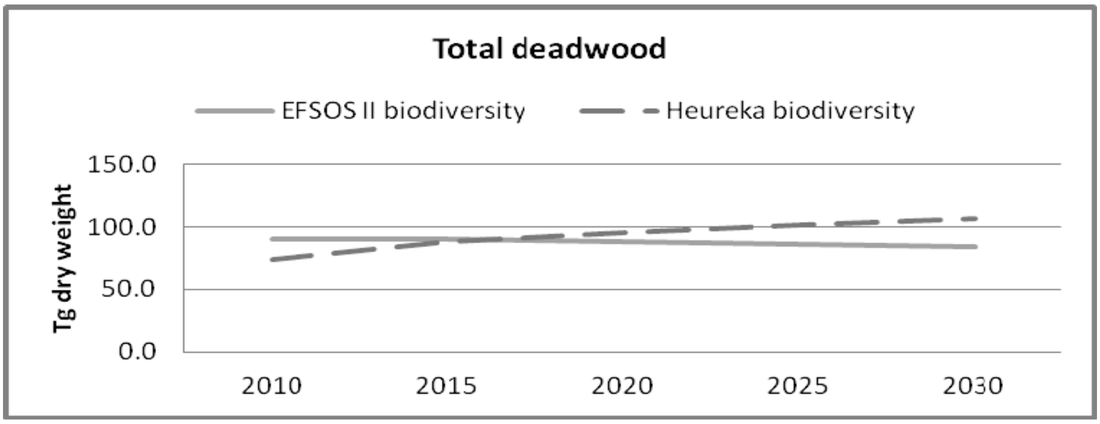

Figure 18 Total amount of deadwood (in Tg dry weight)

Despite differences as to NFI data used and models used, both biodiversity scenarios show that those parameters that are related with conservation and biodiversity are developing positively. Even though, development of deadwood in the EFSOS II scenario is not increasing as expected, the increase in areas protected should lead to an increase in the amount of deadwood.

3.4.2 Wood energy scenarios

Both the EFSOS II wood energy scenario (EWES) and the corresponding scenario created in this thesis (HWES) entail increased harvesting. As previously explained, due to the optimization model used, in the HWES the harvesting peaks the first five-year. By 2030, harvest levels in EWES and HWES have converged (Figure 19).

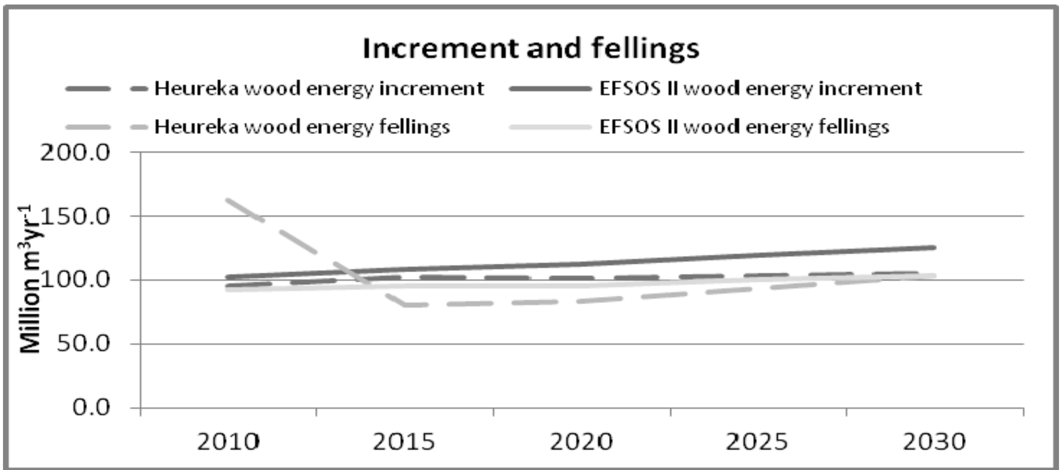

Figure 19 Net annual increment and gross annual fellings (in million m^3)

Both of the simulations result in a positive development (except first period of Heureka simulation) of residues extraction and are therefore supporting the development of bioenergy market (Figure 20). Furthermore the tradeoffs between ecological services such as deadwood have also showed interesting result. Harvesting residues will impact the amount of deadwood in the forest which in both of the scenarios is significantly lower than in corresponding *biodiversity scenarios.* Interestingly, the HWES shows an increasing trend in the amount of deadwood, which is not the case in the EWES (Figure 21). *A*n interesting result can also be observed as regards the development of soil carbon (Figure 22). Where, regardless that the management is very different the difference in soil carbon is not significant.

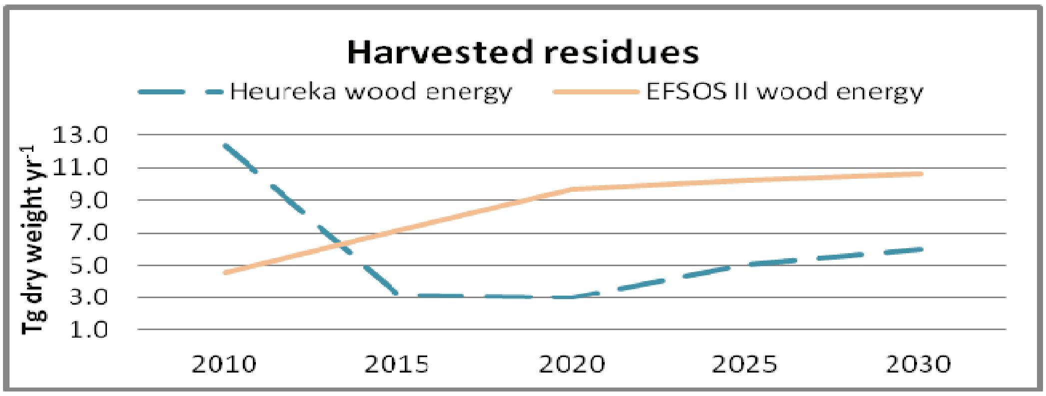

Figure 20 Total amount of annually extracted residues (in Tg dry weight)

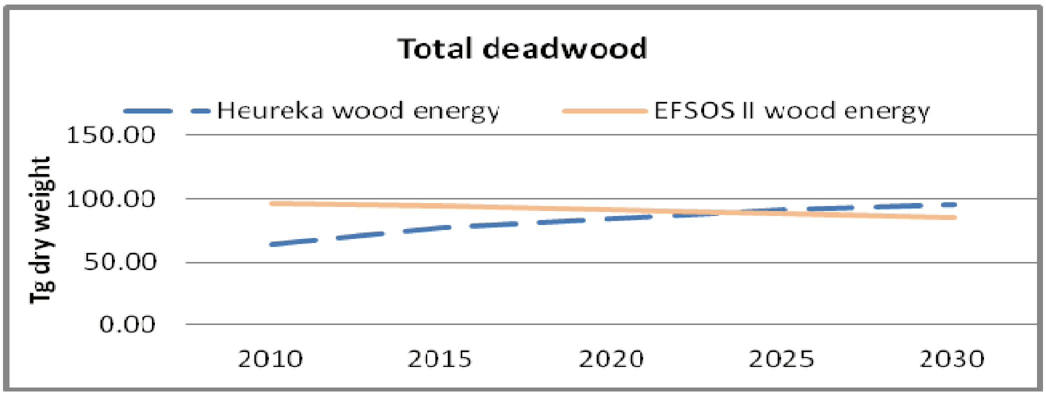

Figure 21 Total amount of deadwood (in Tg dry weight)

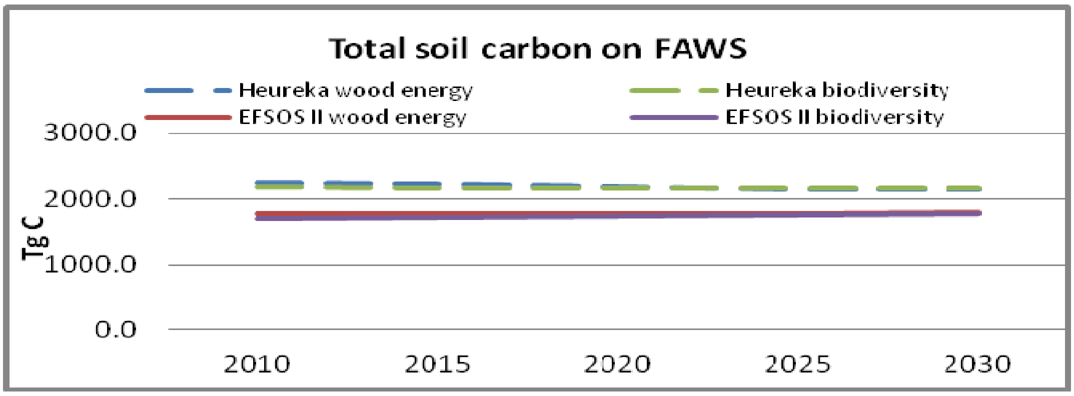

Figure 22 Total amount of soil carbon (Tg C)

4. Discussion

The wood energy scenario presents results for the development of the forest resource when the overriding management objective is maximize the production of woody biomass, given a sustainable development of the growing stock. Shortening rotation periods to increase harvesting rates and the supply of woody biomass for material and energy appears to be compatible with sustainability in the sense of maintaining a stable growing stock over time. This scenario would result in a significant increase in the harvesting potential compared to the scenario prioritizing biodiversity.

The elevated harvest level of the wood energy scenario would come at a price, though. Hence, the extent of old forest would drastically decrease; indeed there would be no forests older than 100 years in the future. This, in combination with harvest residues extraction would lead to considerably lower amounts of deadwood as compared with what would be the case if biodiversity was the overriding policy objective, negatively impacting biodiversity (Verkerk et al.. 2009) as deadwood is essential, e.g., for saproxylic beetle diversity (Hjältén et al.. 2010).

A somewhat striking result is that notwithstanding rather strong measures to increase biodiversity the biodiversity scenario has a sustained harvest potential that is at least as high as current harvest levels; 89.5 and 88.8 million m^3 in 2010 and 2011 respectively (source: Swedish Forest Agency 2012). However, an increasing share of the future raw material would come from hardwood if this scenario would materialize; something which would entail a difficult adjustment for a forest industry oriented towards softwood.

Further, the biodiversity scenario results in ten percent more total carbon stored in one hundred years compared to the wood energy scenario. However, to get a complete picture as regards climate change mitigation, one should take into account the substitution effect of using wood-based material and energy instead of fossil fuel based ditto. According to, e.g., Eriksson (2007), using biofuels instead of fossil fuels significantly reduces CO_2 emissions. Therefore, even though the removing of residues has a negative influence on soil carbon storage, the benefits of these residues if they are used for producing bioenergy are significant. Additionally, Eriksson (2007) concludes that if the objective of the forest management is to maximize the carbon stock in standing biomass, an intensive management regime is the best option.

Ever since the 1990s outdoor recreation has been a part of European forest and land policies. Relevant European documents, such as Indicators for Sustainable Forest Management, reports from Ministerial Conference on the protection of Forest in Europe, EU Forest Action Plan etc., all address the issues considering outdoor recreation as one of three sustainability functions of forest (Mann et al.. 2010). As a member of the EU, Sweden has also studied the issues and considered recreational values in a process of creating forest policies and management plans. Furthermore, in the Forestry Act of 1994 Sweden has stated that timer production and environmental values are equally important (National Boart of Forestry, 1994 as stated in Mann et al.. 2010). According to the simulation results, neither management focusing biomass production nor prioritizing biodiversity, as interpreted in this study, can be reconciled with high recreational values. In fact, both seem equally detrimental, but presumably for different reasons (e.g., amount of deadwood versus harvest residues extraction).

5. Concluding remarks

The two scenarios created in this research are presenting two possible futures for the Sweden's forest resource, given two contrasting, overriding, management objectives. First, a *biodiversity scenario* based on the prolongation of rotation periods, an increase in areas protected, conversion to more broadleaves, and no harvest residues extraction of any kind. This scenario resulted in a significant increase in the amount of deadwood (linked to biodiversity, e.g., saproxylic beetles) as well as carbon stored (mitigating climate change). However, potential harvest levels are considerably lower than in the other scenario, the *wood energy scenario*.

The *wood energy scenario* focuses on woody-biomass production, and can thus be said to represent climate change mitigation through the substitution of fossil fuel based materials and energy. Based on shortening of rotation periods and the extraction of harvest residues; this scenario results in significantly higher potential harvest volumes. The downsides are considerably lower amounts of deadwood as well as carbon stored in soil, deadwood, and in living biomass.

Hence, this thesis illustrates the potential trade-off between biomass production and biodiversity. The issue of total carbon balance is, as already mentioned, a complex issue. Hence, though the biodiversity scenario results in ten percent more total carbon stored in one hundred years compared to the wood energy scenario, a complete picture as regards climate change mitigation should include the substitution effect of using wood-based material and energy instead of fossil fuel based ditto.

Finally, according to the simulation results, neither management focusing biomass production nor biodiversity, as interpreted in this study, can be reconciled with high recreational values. In fact, both seem equally detrimental. This is of particular interest, considering the debate evoked by a series of newspaper articles by the journalist Zaremba. One of the points made were that, even though biodiversity values are better catered for now than previously, social values are to a large extent neglected (Zaremba, 2012).

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